WHAT IS CLAIMED IS:

1. A directional measuring device that measures a direction of a body of the directional measuring device in a three-dimensional space including an X-axis indicating magnetic north on a horizontal plane, a Y-axis orthogonal to the X-axis on the horizontal plane, and a Z-axis orthogonal to the horizontal plane, assuming that the body points towards an x-axis, comprising:

an x-axis geomagnetic force detector that detects a geomagnetic force along the x-axis;

an x-axis tilt angle detector that detects an x-axis tilt angle that is an angle between the horizontal plane and the x-axis;

a determining unit that determines the x-axis tilt angle as a rotation angle that is an angle by which the x-axis needs to be rotated around the Y-axis so as to be in the horizontal plane; and

an azimuth calculator that calculates an azimuth of the body based on the geomagnetic force and the rotation angle.

2. The directional measuring device according to claim 1, further comprising:

a y-axis geomagnetic force detector that detects a geomagnetic force along a y-axis that is orthogonal to the x-axis;

a z-axis geomagnetic force detector that detects a geomagnetic force along a z-axis that is orthogonal to both the x-axis and the y-axis;

a y-axis tilt angle detector that detects a y-axis tilt angle that is angle between the horizontal plane and the y-axis; and

a rotation angle calculator that calculates a rotation angle based on

both the x-axis tilt angle and the y-axis tilt angle, wherein the rotation angle is an angle by which the y-axis needs to be rotated around the X-axis so as to be in the horizontal plane when the x-axis is rotated by the x-axis tilt angle around the Y-axis so as to be in the horizontal plane to cause the y-axis to rotate following rotation of the x-axis, wherein

the azimuth calculator calculates an azimuth of the body based on the geomagnetic forces detected by both the y-axis geomagnetic force detector and the z-axis geomagnetic force detector and the rotation angle calculated.

3. The directional measuring device according to claim 2, wherein the azimuth calculator further comprises:

a sine calculator that calculates sine of the azimuth of the body based on the geomagnetic forces detected by both the y-axis geomagnetic force detector and the z-axis geomagnetic force detector and the rotation angle calculated by the rotation angle calculator;

a cosine calculator that calculates cosine of the azimuth of the body based on the geomagnetic force detected by the x-axis geomagnetic force detector and the rotation angle determined by the determining unit; and

an identifying unit that identifies an angular range of the azimuth based on the sine and the cosine of the azimuth,

wherein the azimuth calculator calculates the azimuth based on one among the sine and the cosine of the azimuth and a tangent value, and of the angular range identified by the identifying unit, the tangent being obtained from the sine and the cosine.

4. The directional measuring device according to claim 2, wherein the rotation angle calculator calculates the rotation angle based on a coordinate expression for rotations three times expressed by an expression

$$\begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} \cos\beta & 0 & -\sin\beta \\ 0 & 1 & 0 \\ \sin\beta & 0 & \cos\beta \end{bmatrix} \times \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha \\ 0 & -\sin\alpha & \cos\alpha \end{bmatrix}$$

where α is a rotation angle around the X-axis, β is an x-axis tilt angle as a rotation angle around the Y-axis, and θ is a rotation angle around the Z-axis as an azimuth of the body.

5. The directional measuring device according to claim 1, wherein the azimuth angle calculator further comprises:

a dip input unit that receives a dip between a geomagnetic vector at a present position of the body and the horizontal plane, wherein

the azimuth calculator calculates the azimuth based on the dip.

6. The directional measuring device according to claim 1, wherein the azimuth angle calculator further comprises:

a declination input unit that receives a declination between the magnetic north at a present position of the body and the true north, wherein

the azimuth calculator calculates the azimuth based on the declination.

7. A directional measuring device that measures a direction of a body of the directional measuring device in a three-dimensional space including an

X-axis indicating magnetic north on a horizontal plane, a Y-axis orthogonal to the X-axis on the horizontal plane, and a Z-axis orthogonal to the horizontal plane, assuming that the body points towards an x-axis, comprising:

a y-axis geomagnetic force detector that detects a geomagnetic force along a y-axis that is orthogonal to the x-axis;

a z-axis geomagnetic force detector that detects a geomagnetic force along a z-axis that is orthogonal to both the x-axis and the y-axis;

an x-axis tilt angle detector that detects an x-axis tilt angle that is an angle between the horizontal plane and the x-axis;

a y-axis tilt angle detector that detects a y-axis tilt angle that is angle between the horizontal plane and the y-axis;

a rotation angle calculator that calculates a rotation angle based on both the x-axis tilt angle and the y-axis tilt angle, wherein the rotation angle is an angle by which the y-axis needs to be rotated around the X-axis so as to be in the horizontal plane when the x-axis is rotated by the x-axis tilt angle around the Y-axis so as to be in the horizontal plane to cause the y-axis to rotate following rotation of the x-axis; and

an azimuth calculator that calculates an azimuth of the body based on the geomagnetic forces detected by both the y-axis geomagnetic force detector and the z-axis geomagnetic force detector and the rotation angle.

8. The directional measuring device according to claim 7, wherein the rotation angle calculator calculates the rotation angle based on a coordinate expression for rotations three times expressed by an expression

$$\begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} \cos\beta & 0 & -\sin\beta \\ 0 & 1 & 0 \\ \sin\beta & 0 & \cos\beta \end{bmatrix} \times \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha \\ 0 & -\sin\alpha & \cos\alpha \end{bmatrix}$$

where α is a rotation angle around the X-axis, β is an x-axis tilt angle as a rotation angle around the Y-axis, and θ is a rotation angle around the Z-axis as an azimuth of the body.

9. The directional measuring device according to claim 7, wherein the azimuth angle calculator further comprises:

a dip input unit that receives a dip between a geomagnetic vector at a present position of the body and the horizontal plane, wherein

the azimuth calculator calculates the azimuth based on the dip.

10. The directional measuring device according to claim 7, wherein the azimuth angle calculator further comprises:

a declination input unit that receives a declination between the magnetic north at a present position of the body and the true north, wherein

the azimuth calculator calculates the azimuth based on the declination.

11. A directional measuring device that measures a direction of a body of the directional measuring device in a three-dimensional space including an X-axis indicating magnetic north on a horizontal plane, a Y-axis orthogonal to the X-axis on the horizontal plane, and a Z-axis orthogonal to the horizontal plane, assuming that the body points towards an x-axis, comprising:

a first-axis geomagnetic force detector that detects a geomagnetic force along a first axis from among the x-axis, a y-axis that is orthogonal to the x-axis, and a z-axis that is orthogonal to both the x-axis and the y-axis;

a second-axis geomagnetic force detector that detects a geomagnetic force along a second axis other than the first axis from among the x-axis, the y-axis, and the z-axis;

a total geomagnetic force input unit that receives a total geomagnetic force at a present position of the body, wherein the total geomagnetic force is a vector addition of geomagnetic forces along the X-axis, the Y-axis, and the Z-axis;

a geomagnetic force calculator that calculates a geomagnetic force along an axis other than the first axis and the second axis, from among the x-axis, the y-axis, and the z-axis based on the total geomagnetic force and the geomagnetic forces along both the first axis and the second axis;

an x-axis tilt angle detector that detects an x-axis tilt angle that is an angle between the horizontal plane and the x-axis;

a determining unit that determines the x-axis tilt angle as a rotation angle that is an angle by which the x-axis needs to be rotated around the Y-axis so as to be in the horizontal plane; and

an azimuth calculator that calculates an azimuth of the body based on the geomagnetic force along the x-axis and the rotation angle.

12. A directional measuring device that measures a direction of a body of the directional measuring device in a three-dimensional space including an X-axis indicating magnetic north on a horizontal plane, a Y-axis orthogonal to

the X-axis on the horizontal plane, and a Z-axis orthogonal to the horizontal plane, assuming that the body points towards an x-axis, comprising:

a first-axis geomagnetic force detector that detects a geomagnetic force along a first axis from among the x-axis, a y-axis that is orthogonal to the x-axis, and a z-axis that is orthogonal to both the x-axis and the y-axis;

a second-axis geomagnetic force detector that detects a geomagnetic force along a second axis other than the first axis from among the x-axis, the y-axis, and the z-axis;

a total geomagnetic force input unit that receives a total geomagnetic force at a present position of the body, wherein the total geomagnetic force is a vector addition of geomagnetic forces along the X-axis, the Y-axis, and the Z-axis;

a geomagnetic force calculator that calculates a geomagnetic force along an axis other than the first axis and the second axis, from among the x-axis, the y-axis, and the z-axis based on the total geomagnetic force and the geomagnetic forces along both the first axis and the second axis;

an x-axis tilt angle detector that detects an x-axis tilt angle that is an angle between the horizontal plane and the x-axis;

a y-axis tilt angle detector that detects a y-axis tilt angle that is an angle between the horizontal plane and the y-axis;

a rotation angle calculator that calculates a rotation angle based on both the x-axis tilt angle and the y-axis tilt angle, wherein the rotation angle is an angle by which the y-axis needs to be rotated around the X-axis so as to be in the horizontal plane when the x-axis is rotated by the x-axis tilt angle around the Y-axis so as to be in the horizontal plane to cause the y-axis to

rotate following rotation of the x-axis; and

an azimuth calculator that calculates an azimuth of the body based on the geomagnetic forces along the y-axis and the z-axis and the rotation angle.

13. A directional measuring method of measuring a direction of a body of the directional measuring device in a three-dimensional space including an X-axis indicating magnetic north on a horizontal plane, a Y-axis orthogonal to the X-axis on the horizontal plane, and a Z-axis orthogonal to the horizontal plane, assuming that the body points towards an x-axis, comprising:

detecting a geomagnetic force along the x-axis;

detecting an x-axis tilt angle that is an angle between the horizontal plane and the x-axis;

determining the x-axis tilt angle as a rotation angle that is an angle by which the x-axis needs to be rotated around the Y-axis so as to be in the horizontal plane; and

calculating an azimuth of the body based on the geomagnetic force and the rotation angle.

14. The directional measuring method according to claim 13, further comprising:

detecting a geomagnetic force along a y-axis that is orthogonal to the x-axis;

detecting a geomagnetic force along a z-axis that is orthogonal to both the x-axis and the y-axis;

detecting a y-axis tilt angle that is angle between the horizontal plane

and the y-axis; and

calculating a rotation angle based on both the x-axis tilt angle and the y-axis tilt angle, wherein the rotation angle is an angle by which the y-axis needs to be rotated around the X-axis so as to be in the horizontal plane when the x-axis is rotated by the x-axis tilt angle around the Y-axis so as to be in the horizontal plane to cause the y-axis to rotate following rotation of the x-axis, wherein

the calculating the azimuth includes calculating the azimuth of the body based on the geomagnetic forces along both the y-axis and the z-axis and the rotation angle calculated.

15. The directional measuring method according to claim 14, wherein the calculating the azimuth includes:

calculating sine of the azimuth of the body based on the geomagnetic forces along both the y-axis and the z-axis and the rotation angle calculated;

calculating cosine of the azimuth of the body based on the geomagnetic force along the x-axis and the rotation angle determined;

identifying an angular range of the azimuth based on the sine and the cosine of the azimuth; and

calculating the azimuth based on one among the sine and the cosine of the azimuth and tangent, and the angular range of the azimuth identified, the tangent being obtained from the sine and the cosine.

16. The directional measuring method according to claim 14, wherein the calculating the rotation angle includes calculating the rotation angle based on

a coordinate expression for rotations three times expressed by an expression

$$\begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} \cos\beta & 0 & -\sin\beta \\ 0 & 1 & 0 \\ \sin\beta & 0 & \cos\beta \end{bmatrix} \times \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha \\ 0 & -\sin\alpha & \cos\alpha \end{bmatrix}$$

where α is a rotation angle around the X-axis, β is an x-axis tilt angle as a rotation angle around the Y-axis, and θ is a rotation angle around the Z-axis as an azimuth of the body.

17. The directional measuring method according to claim 13, wherein the calculating the azimuth angle includes:

receiving a dip between a geomagnetic vector at a present position of the body and the horizontal plane, wherein

the calculating the azimuth includes calculating the azimuth based on the dip.

18. The directional measuring method according to claim 13, wherein the calculating the azimuth angle includes:

receiving a declination between the magnetic north at a present position of the body and the true north, wherein

the calculating the azimuth includes calculating the azimuth based on the declination.

19. A directional measuring method of measuring a direction of a body of the directional measuring device in a three-dimensional space including an X-axis indicating magnetic north on a horizontal plane, a Y-axis orthogonal to

the X-axis on the horizontal plane, and a Z-axis orthogonal to the horizontal plane, assuming that the body points towards an x-axis, comprising:

detecting a geomagnetic force along a y-axis that is orthogonal to the x-axis;

detecting a geomagnetic force along a z-axis that is orthogonal to both the x-axis and the y-axis;

detecting an x-axis tilt angle that is an angle between the horizontal plane and the x-axis;

detecting a y-axis tilt angle that is angle between the horizontal plane and the y-axis;

calculating a rotation angle based on both the x-axis tilt angle and the y-axis tilt angle, wherein the rotation angle is an angle by which the y-axis needs to be rotated around the X-axis so as to be in the horizontal plane when the x-axis is rotated by the x-axis tilt angle around the Y-axis so as to be in the horizontal plane to cause the y-axis to rotate following rotation of the x-axis; and

calculating an azimuth of the body based on the geomagnetic forces detected along both the y-axis and the z-axis and the rotation angle.

20. The directional measuring method according to claim 19, wherein the calculating the rotation angle includes calculating the rotation angle based on a coordinate expression for rotations three times expressed by an expression

$$\begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} \cos\beta & 0 & -\sin\beta \\ 0 & 1 & 0 \\ \sin\beta & 0 & \cos\beta \end{bmatrix} \times \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha \\ 0 & -\sin\alpha & \cos\alpha \end{bmatrix}$$

where α is a rotation angle around the X-axis, β is an x-axis tilt angle as a rotation angle around the Y-axis, and θ is a rotation angle around the Z-axis as an azimuth of the body.

21. The directional measuring method according to claim 19, wherein the calculating the azimuth angle includes:

receiving a dip between a geomagnetic vector at a present position of the body and the horizontal plane, wherein

the calculating the azimuth includes calculating the azimuth based on the dip.

22. The directional measuring method according to claim 19, wherein the calculating the azimuth angle includes:

receiving a declination between the magnetic north at a present position of the body and the true north, wherein

the calculating the azimuth includes calculating the azimuth based on the declination.

23. A directional measuring method of measuring a direction of a body of the directional measuring device in a three-dimensional space including an X-axis indicating magnetic north on a horizontal plane, a Y-axis orthogonal to the X-axis on the horizontal plane, and a Z-axis orthogonal to the horizontal plane, assuming that the body points towards an x-axis, comprising:

detecting a geomagnetic force along a first axis from among the x-axis, a y-axis that is orthogonal to the x-axis, and a z-axis that is orthogonal to both

the x-axis and the y-axis;

detecting a geomagnetic force along a second axis other than the first axis from among the x-axis, the y-axis, and the z-axis;

receiving a total geomagnetic force at a present position of the body, wherein the total geomagnetic force is a vector addition of geomagnetic forces along the X-axis, the Y-axis, and the Z-axis;

calculating a geomagnetic force along an axis other than the first axis and the second axis, from among the x-axis, the y-axis, and the z-axis based on the total geomagnetic force and the geomagnetic forces along both the first axis and the second axis;

detecting an x-axis tilt angle that is an angle between the horizontal plane and the x-axis;

determining the x-axis tilt angle as a rotation angle that is an angle by which the x-axis needs to be rotated around the Y-axis so as to be in the horizontal plane; and

calculating an azimuth of the body based on the geomagnetic force along the x-axis and the rotation angle.

24. A directional measuring method of measuring a direction of a body of the directional measuring device in a three-dimensional space including an X-axis indicating magnetic north on a horizontal plane, a Y-axis orthogonal to the X-axis on the horizontal plane, and a Z-axis orthogonal to the horizontal plane, assuming that the body points towards an x-axis, comprising:

detecting a geomagnetic force along a first axis from among the x-axis, a y-axis that is orthogonal to the x-axis, and a z-axis that is orthogonal to both

the x-axis and the y-axis;

detecting a geomagnetic force along a second axis other than the first axis from among the x-axis, the y-axis, and the z-axis;

receiving a total geomagnetic force at a present position of the body, wherein the total geomagnetic force is a vector addition of geomagnetic forces along the X-axis, the Y-axis, and the Z-axis;

calculating a geomagnetic force along an axis other than the first axis and the second axis, from among the x-axis, the y-axis, and the z-axis based on the total geomagnetic force and the geomagnetic forces along both the first axis and the second axis;

detecting an x-axis tilt angle that is an angle between the horizontal plane and the x-axis;

detecting a y-axis tilt angle that is an angle between the horizontal plane and the y-axis;

calculating a rotation angle based on both the x-axis tilt angle and the y-axis tilt angle, wherein the rotation angle is an angle by which the y-axis needs to be rotated around the X-axis so as to be in the horizontal plane when the x-axis is rotated by the x-axis tilt angle around the Y-axis so as to be in the horizontal plane to cause the y-axis to rotate following rotation of the x-axis; and

calculating an azimuth of the body based on the geomagnetic forces along the y-axis and the z-axis and the rotation angle.

25. A computer program that realizes on a computer a directional measuring method of measuring a direction of a body of the directional

measuring device in a three-dimensional space including an X-axis indicating magnetic north on a horizontal plane, a Y-axis orthogonal to the X-axis on the horizontal plane, and a Z-axis orthogonal to the horizontal plane, assuming that the body points towards an x-axis, the computer program making the computer execute:

detecting a geomagnetic force along the x-axis;

detecting an x-axis tilt angle that is an angle between the horizontal plane and the x-axis;

determining the x-axis tilt angle as a rotation angle that is an angle by which the x-axis needs to be rotated around the Y-axis so as to be in the horizontal plane; and

calculating an azimuth of the body based on the geomagnetic force and the rotation angle.

26. A computer program that realizes on a computer a directional measuring method of measuring a direction of a body of the directional measuring device in a three-dimensional space including an X-axis indicating magnetic north on a horizontal plane, a Y-axis orthogonal to the X-axis on the horizontal plane, and a Z-axis orthogonal to the horizontal plane, assuming that the body points towards an x-axis, the computer program making the computer execute:

detecting a geomagnetic force along a y-axis that is orthogonal to the x-axis;

detecting a geomagnetic force along a z-axis that is orthogonal to both the x-axis and the y-axis;

detecting an x-axis tilt angle that is an angle between the horizontal plane and the x-axis;

detecting a y-axis tilt angle that is angle between the horizontal plane and the y-axis;

calculating a rotation angle based on both the x-axis tilt angle and the y-axis tilt angle, wherein the rotation angle is an angle by which the y-axis needs to be rotated around the X-axis so as to be in the horizontal plane when the x-axis is rotated by the x-axis tilt angle around the Y-axis so as to be in the horizontal plane to cause the y-axis to rotate following rotation of the x-axis; and

calculating an azimuth of the body based on the geomagnetic forces detected along both the y-axis and the z-axis and the rotation angle.

27. A computer program that realizes on a computer a directional measuring method of measuring a direction of a body of the directional measuring device in a three-dimensional space including an X-axis indicating magnetic north on a horizontal plane, a Y-axis orthogonal to the X-axis on the horizontal plane, and a Z-axis orthogonal to the horizontal plane, assuming that the body points towards an x-axis, the computer program making the computer execute:

detecting a geomagnetic force along a first axis from among the x-axis, a y-axis that is orthogonal to the x-axis, and a z-axis that is orthogonal to both the x-axis and the y-axis;

detecting a geomagnetic force along a second axis other than the first axis from among the x-axis, the y-axis, and the z-axis;

receiving a total geomagnetic force at a present position of the body, wherein the total geomagnetic force is a vector addition of geomagnetic forces along the X-axis, the Y-axis, and the Z-axis;

calculating a geomagnetic force along an axis other than the first axis and the second axis, from among the x-axis, the y-axis, and the z-axis based on the total geomagnetic force and the geomagnetic forces along both the first axis and the second axis;

detecting an x-axis tilt angle that is an angle between the horizontal plane and the x-axis;

determining the x-axis tilt angle as a rotation angle that is an angle by which the x-axis needs to be rotated around the Y-axis so as to be in the horizontal plane; and

calculating an azimuth of the body based on the geomagnetic force along the x-axis and the rotation angle.

28. A computer program that realizes on a computer a directional measuring method of measuring a direction of a body of the directional measuring device in a three-dimensional space including an X-axis indicating magnetic north on a horizontal plane, a Y-axis orthogonal to the X-axis on the horizontal plane, and a Z-axis orthogonal to the horizontal plane, assuming that the body points towards an x-axis, the computer program making the computer execute:

detecting a geomagnetic force along a first axis from among the x-axis, a y-axis that is orthogonal to the x-axis, and a z-axis that is orthogonal to both the x-axis and the y-axis;

detecting a geomagnetic force along a second axis other than the first axis from among the x-axis, the y-axis, and the z-axis;

receiving a total geomagnetic force at a present position of the body, wherein the total geomagnetic force is a vector addition of geomagnetic forces along the X-axis, the Y-axis, and the Z-axis;

calculating a geomagnetic force along an axis other than the first axis and the second axis, from among the x-axis, the y-axis, and the z-axis based on the total geomagnetic force and the geomagnetic forces along both the first axis and the second axis;

detecting an x-axis tilt angle that is an angle between the horizontal plane and the x-axis;

detecting a y-axis tilt angle that is an angle between the horizontal plane and the y-axis;

calculating a rotation angle based on both the x-axis tilt angle and the y-axis tilt angle, wherein the rotation angle is an angle by which the y-axis needs to be rotated around the X-axis so as to be in the horizontal plane when the x-axis is rotated by the x-axis tilt angle around the Y-axis so as to be in the horizontal plane to cause the y-axis to rotate following rotation of the x-axis; and

calculating an azimuth of the body based on the geomagnetic forces along the y-axis and the z-axis and the rotation angle.